Not-So Silent Night: Suomi NPP's Day/Night Band Makes Waves as a Disruptive Technology to Characterization of the Nocturnal Environment

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The VIIRS Day/Night Band

The Day/Night Band (DNB) on the Suomi National Polar-orbiting Partnership (S-NPP) satellite, is part of the Visible/Infrared Imaging Radiometer Suite (VIIRS). With its very high sensitivity to low levels of visible to near-infrared light, it offers a unique new perspective on the night, This poster gives a sampling of the many capabilities, which far exceed what was anticipated.

Comparison to Heritage Technology

The DNB offers marked advances over the legacy Operational Linescan System (OLS) on the Defense Meteorological Satellite Program (DMSP) in terms of spatial resolution, sensitivity, radiometric resolution, and calibration.

Attribute	DMSP/OLS*	VIIRS/DNB on Suomi NPP*
Orbit	Sun-synchronous, ~850 km	Sun-synchronous, 827 km
Nighttime Nodal Overpass Time	~1930 UTC	~0130 UTC
Swath Width	3000 km	3000 km
Spectral Response (FWHM)	Panchromatic 500-900 nm	Panchromatic 500-900 nm
Instantaneous Field of View	5 km (nadir) / ~7 km (edge)	0.740 ± 0.043 km (Scan) / 0.755 ± 0.022 km (track)
Spatial Resolution (Ground Sample Distance)	2.7 km; 'smooth' data	< 0.820 km (Scan) / < 0.750 km (track)
Minimum Detectable Signal	4×10^{-5} W m^{-2} sr^{-1}	3×10^{-5} W m^{-2} sr^{-1}
Noise Floor	~5×10^{-6} W m^{-2} sr^{-1}	~5×10^{-7} W m^{-2} sr^{-1}
Radiometric Quantization	6 bit	13 - 14 bit
Accompanying Spectral Bands	1	11 (night) / 21 (day)
Radiometric Calibration	None	On-Board Solar Diffuser
Saturation	In Urban Cores	None

Spectral Response — Spatial Resolution Improvements
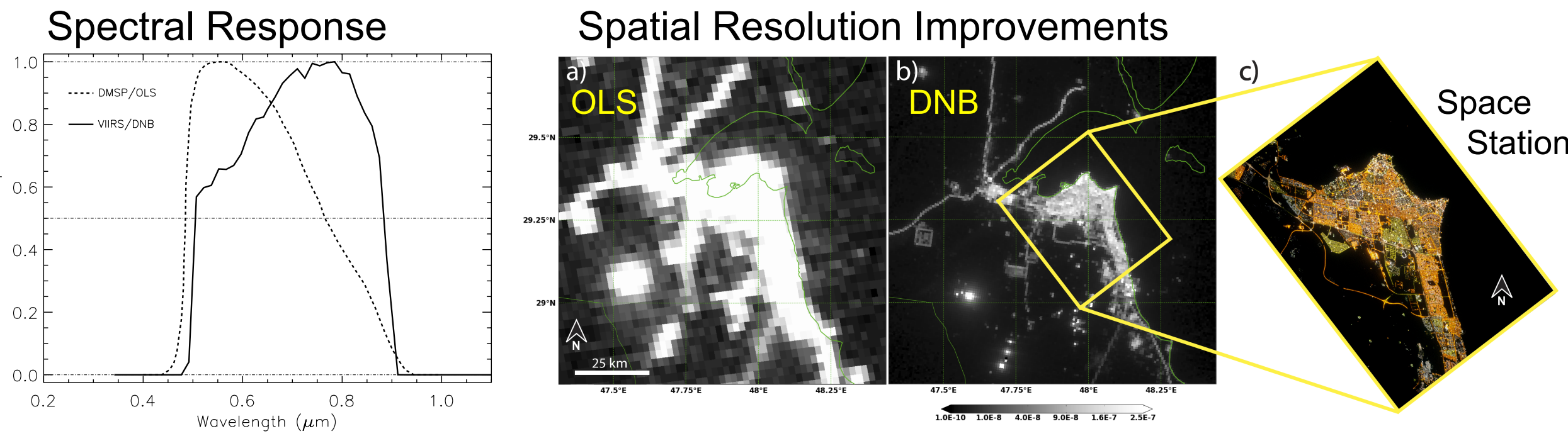
The DNB response is slightly NIR-shifted compared to OLS (giving it an unexpected sensitivity to nightglow), and its spatial resolution is 50-90 times higher.
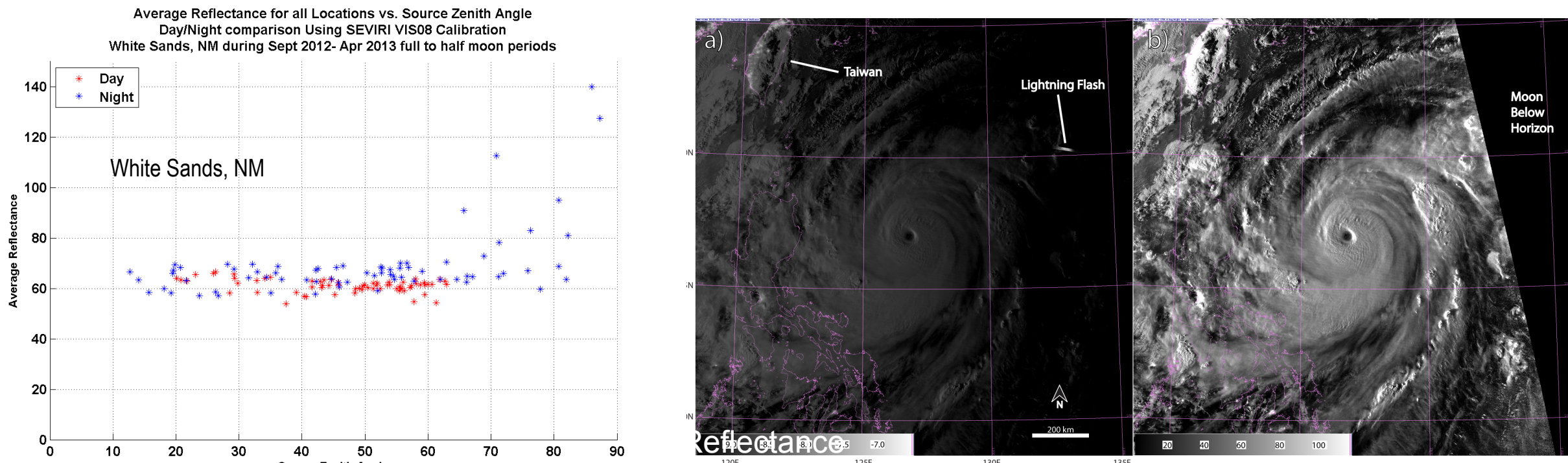
Enabling Quantitative Applications

Taking advantage of the DNB's calibrated measurements of reflected moonlight requires conversion from radiance (I) to reflectance (R) by way of a lunar spectrral irradiance model (F):

$$R_m = \pi I_m / (\mu F_m)$$
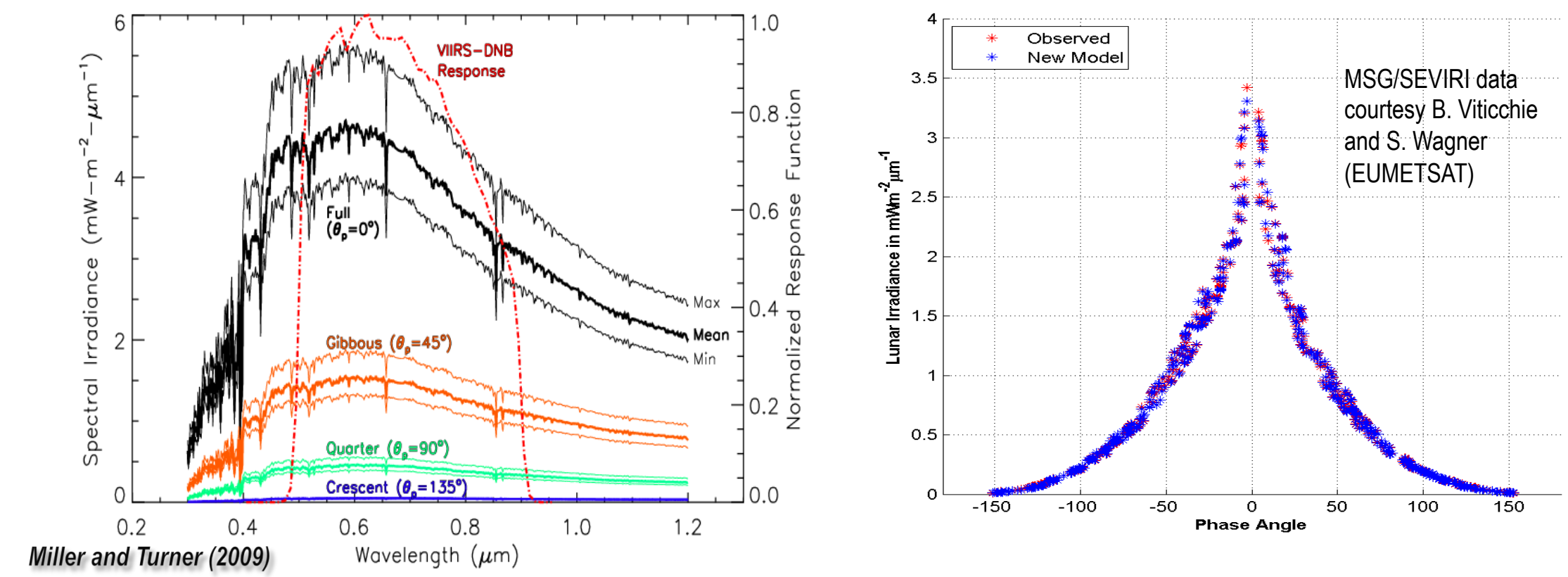
A radiometry-based lunar irradiance model (above-left) has been developed. The model is currently being validated against various surface targets and direct lunar views by satellites (above-right).


Applied to the DNB (above-left), the model enables a kind of Near Constant Contrast (NCC; above-right) but with units of reflectance—providing a way to relate the measurements to cloud optical properties.

On Moonlit Nights

For about ½ of the ~29.5 day lunar cycle (for S-NPP, a period from roughly 2 nights after First Quarter until 2 nights after Last Quarter lunar phase), the DNB can utilize moonlight in a way analogous to daytime visible channels. Shown below are selected examples of how moonlight helps to illuminate the nocturnal environment:

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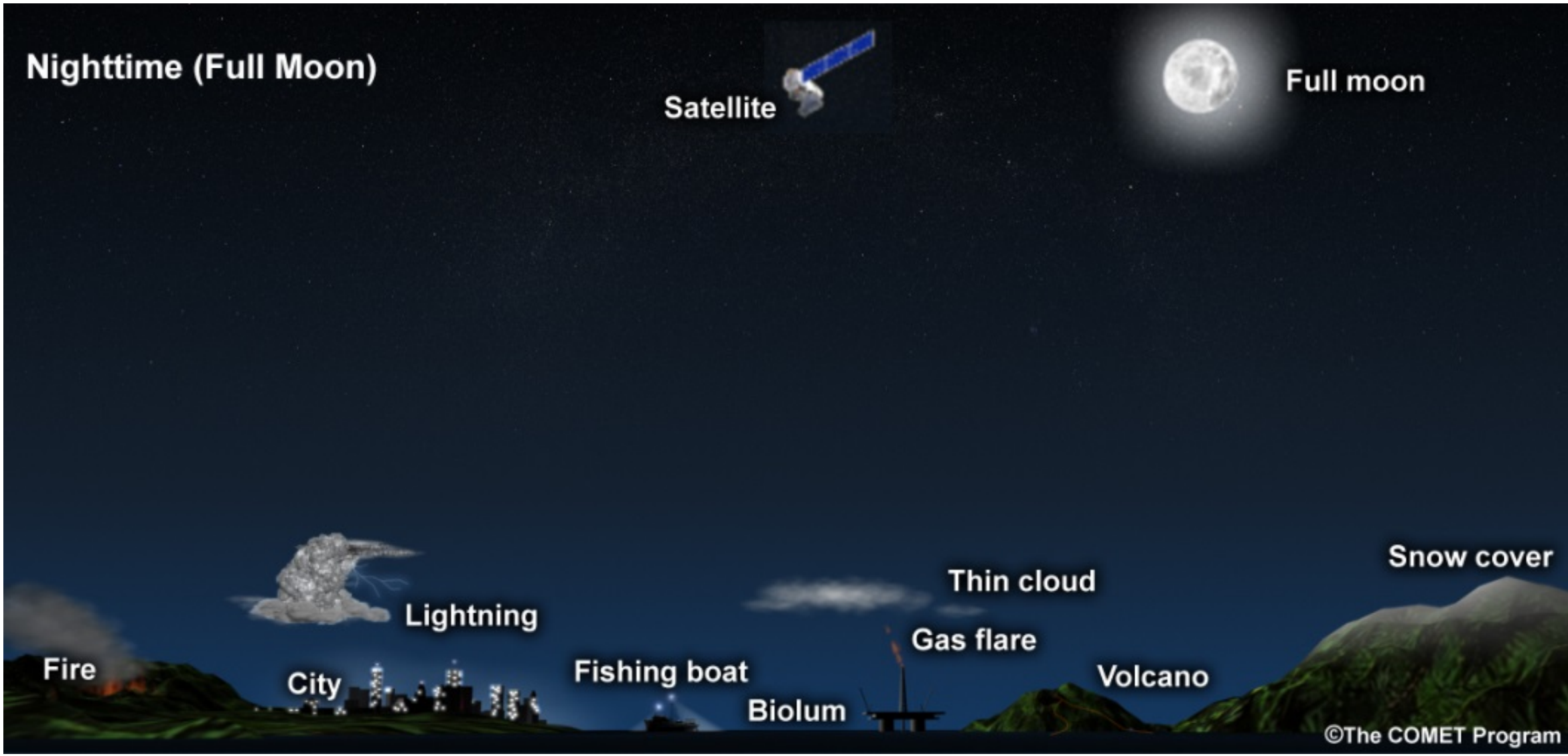
Hurricane Low-Level Circulation
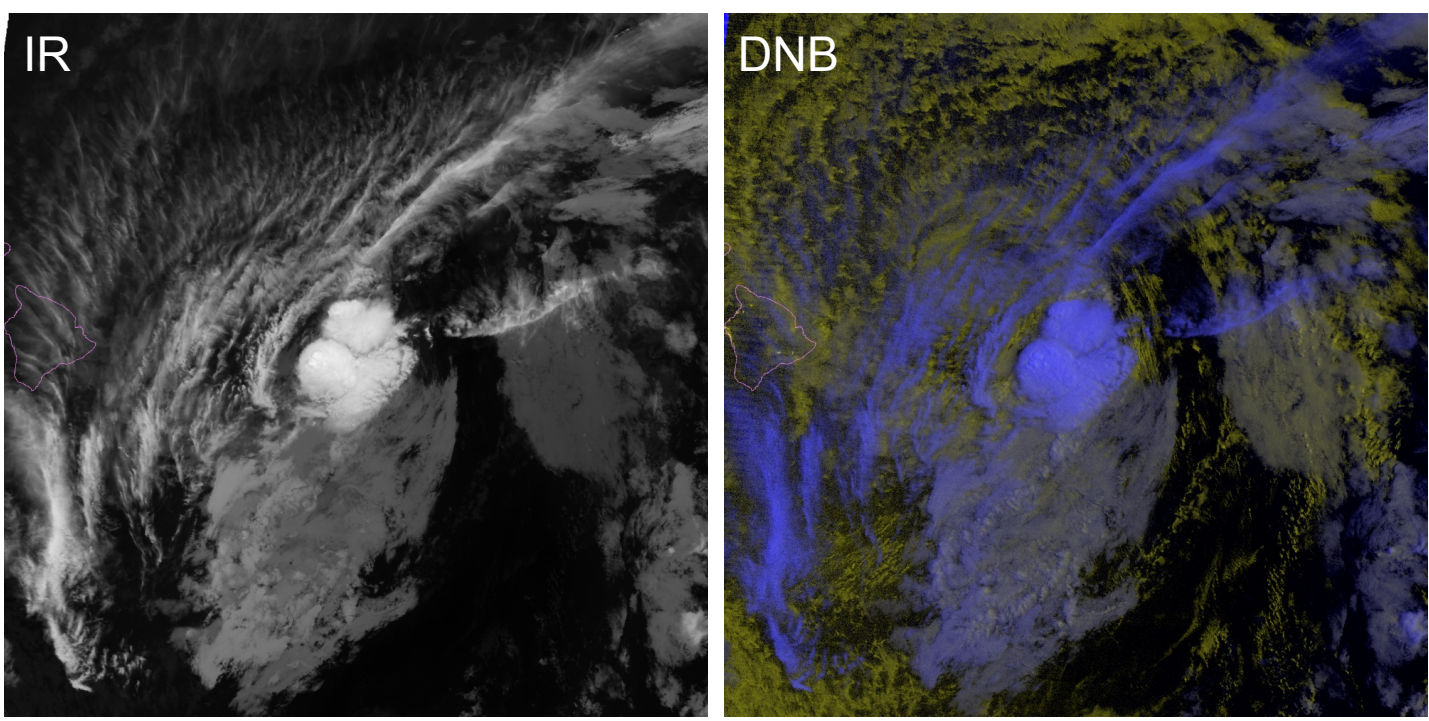
IR imagery (left) misses LLC revealed by low clouds in DNB imagery (right). NWS usage statement below:

"THE CENTER OF FLOSSIE WAS HIDDEN BY HIGH CLOUDS MOST OF THE NIGHT BEFORE VIIRS NIGHTTIME VISUAL (DNB) SATELLITE IMAGERY REVEALED AN EXPOSED LOW LEVEL CIRCULATION CENTER FARTHER NORTH THAN EXPECTED. WE RE-BESTED THE 0600 UTC POSITION BASED ON THE VISIBLE DATA."

NWS CENTRAL PACIFIC HURRICANE CENTER HONOLULU HI, 500 AM HST MON JUL 29 2013

Nocturnal Cloud Optical Depth
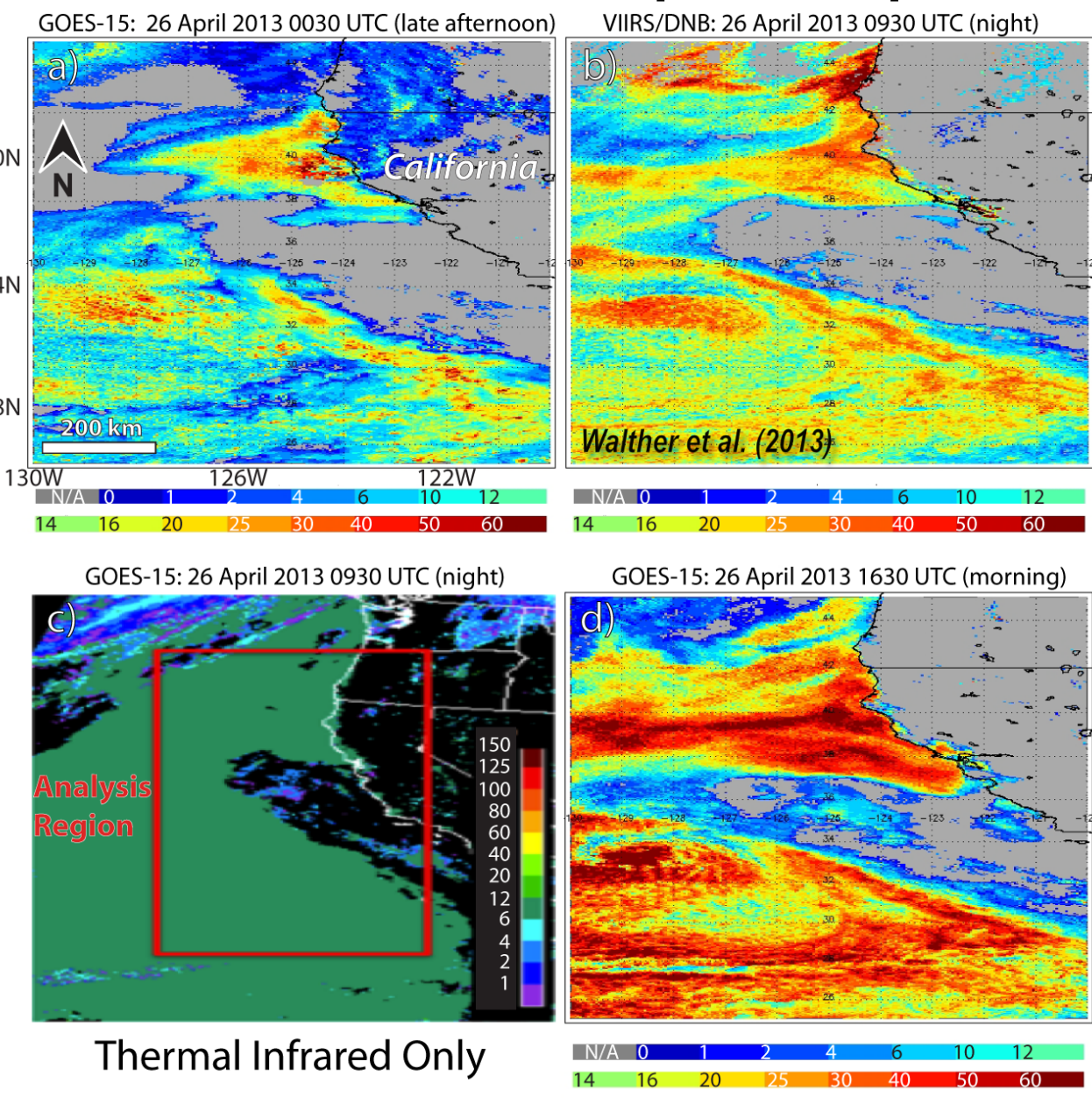
Time sequence of cloud optical depth for stratocumulus off the California coast. Panel b shows the benefits of nighttime lunar information over an IR-only retrieval (c).

Volcanic Ash

Low-level ash features via moonlight

Ocean Features in Moon Glint
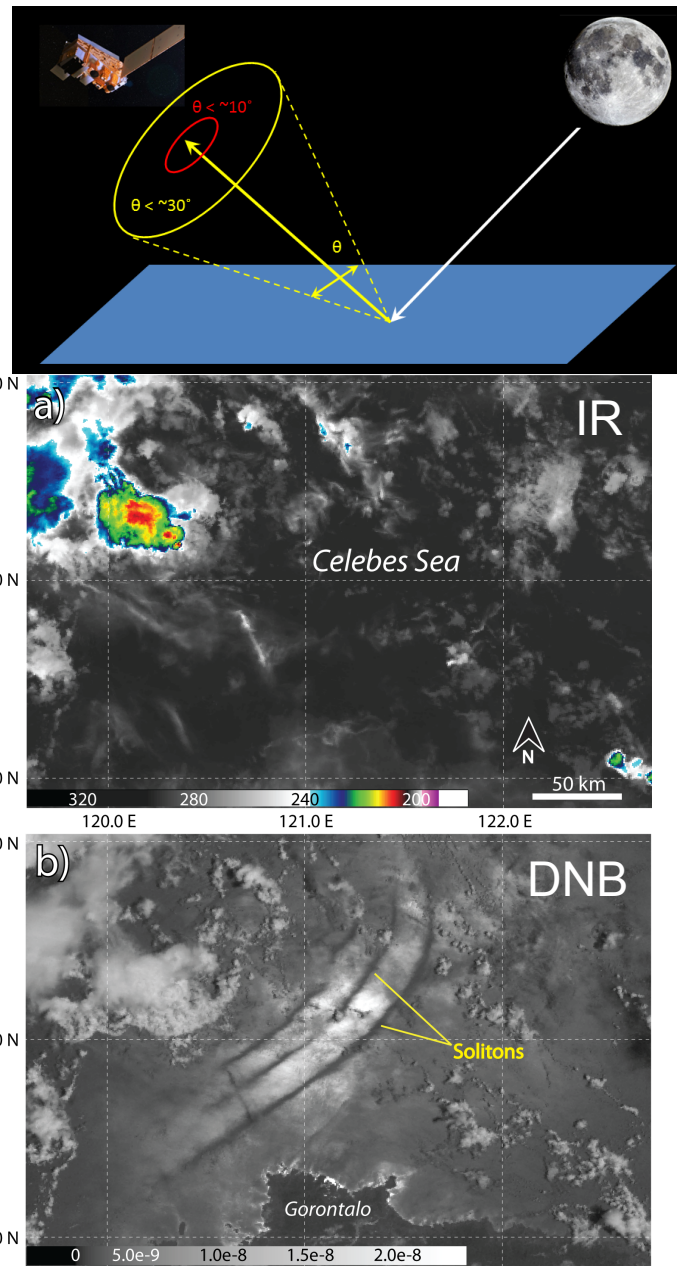
Specular reflection of moonlight reveals sea surface boundaries, oil slicks, and solitary internal (soliton) waves.

Sea Ice Detection Below Clouds

Clouds opaque in the IR (left) can be transparent at visible wavelengths, enabling DNB detection of surface features below them via lunar reflectance (right).

Smoke Plumes

Visible wavelengths offer sensitivity to smaller size parameters

Soil Wetness
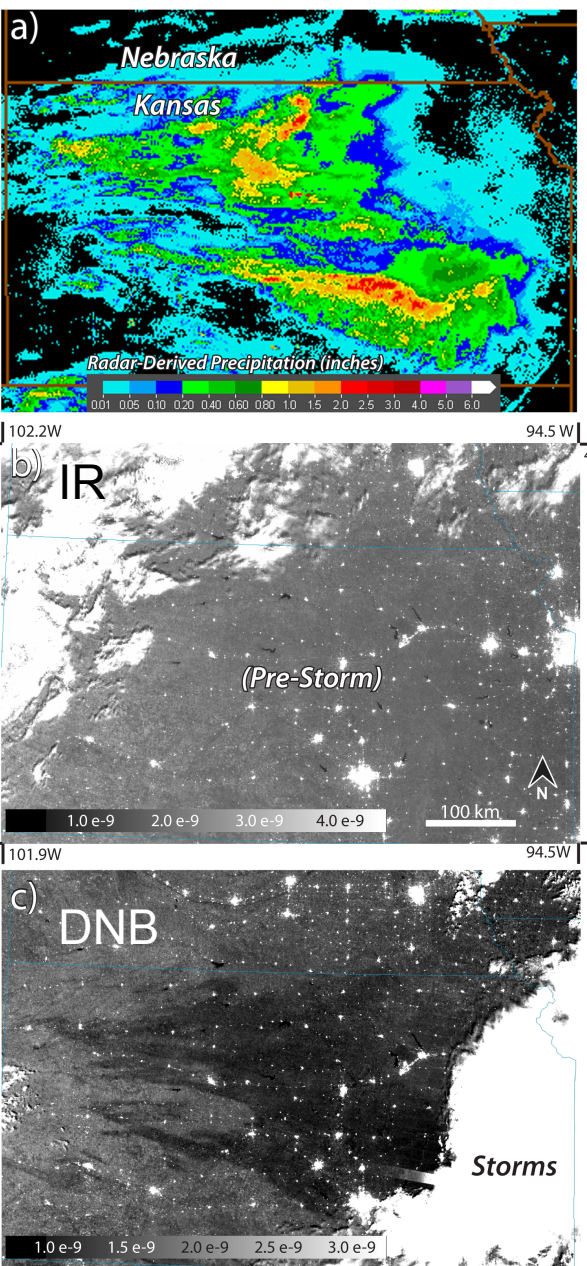
Radar-derived rain accumulation (upper), IR imagery (middle) and DNB showing darkened soils (lower)

Snow Field Detection
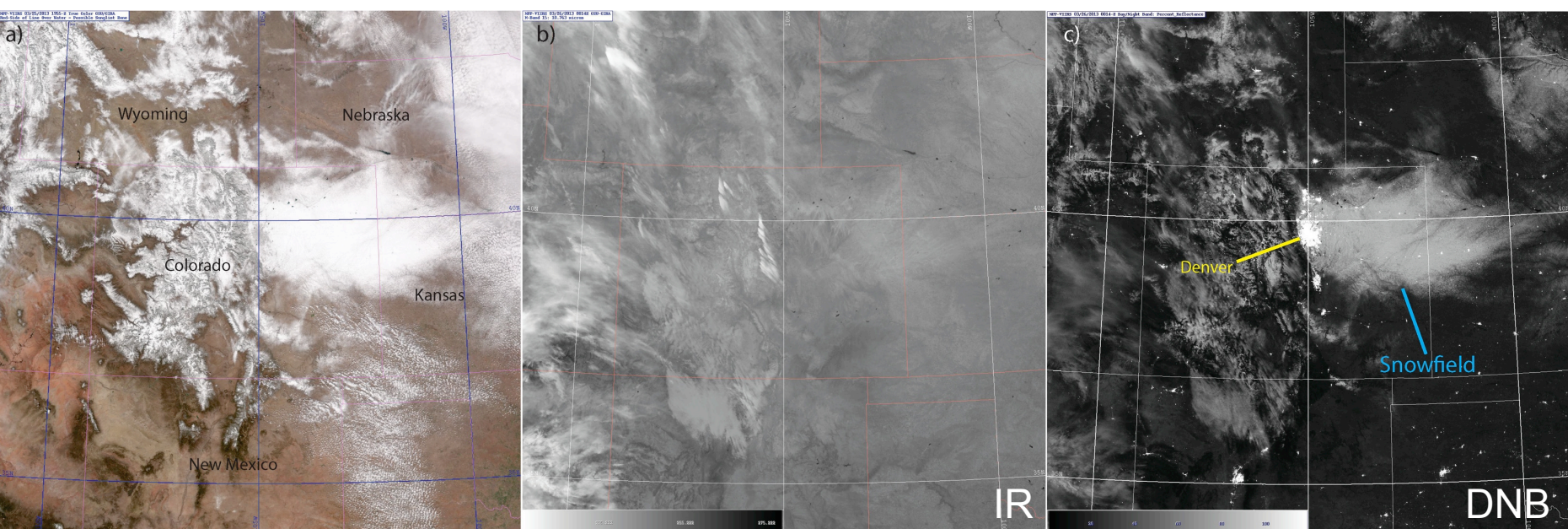
Snow fields readily discernible during the day (left) disappear at night (center) for lack of IR sensitivity. The DNB (right) reveals these regions via lunar reflectance—adding value to surface temperature forecasting.

On Moonless Nights

On nights without moonlight, the DNB continues to provide many useful applications based on emission of light from natural and anthropogenic sources from the surface to top of atmosphere, including some capabilities not imagined at the time of sensor design. Some examples are provided below:

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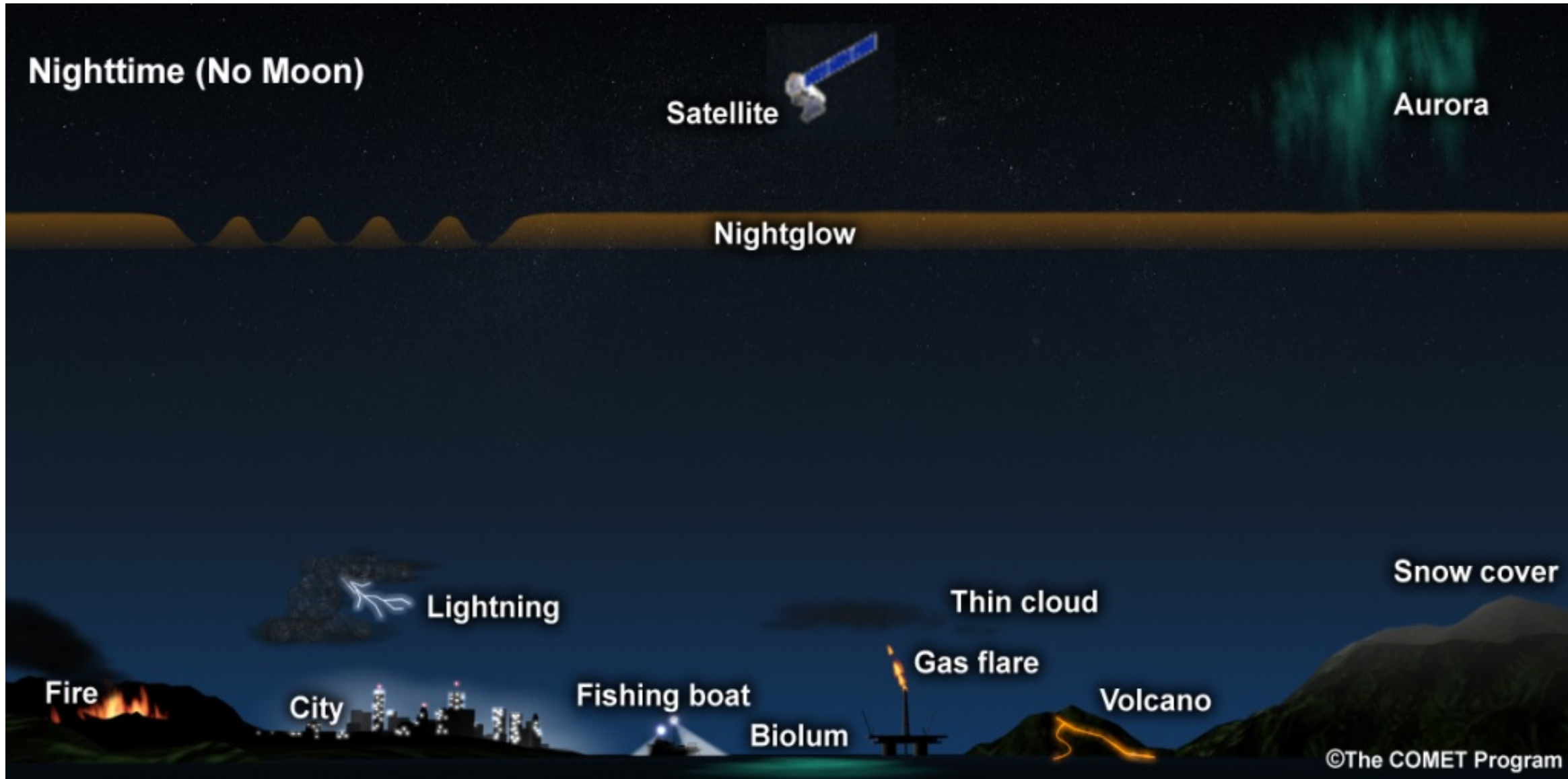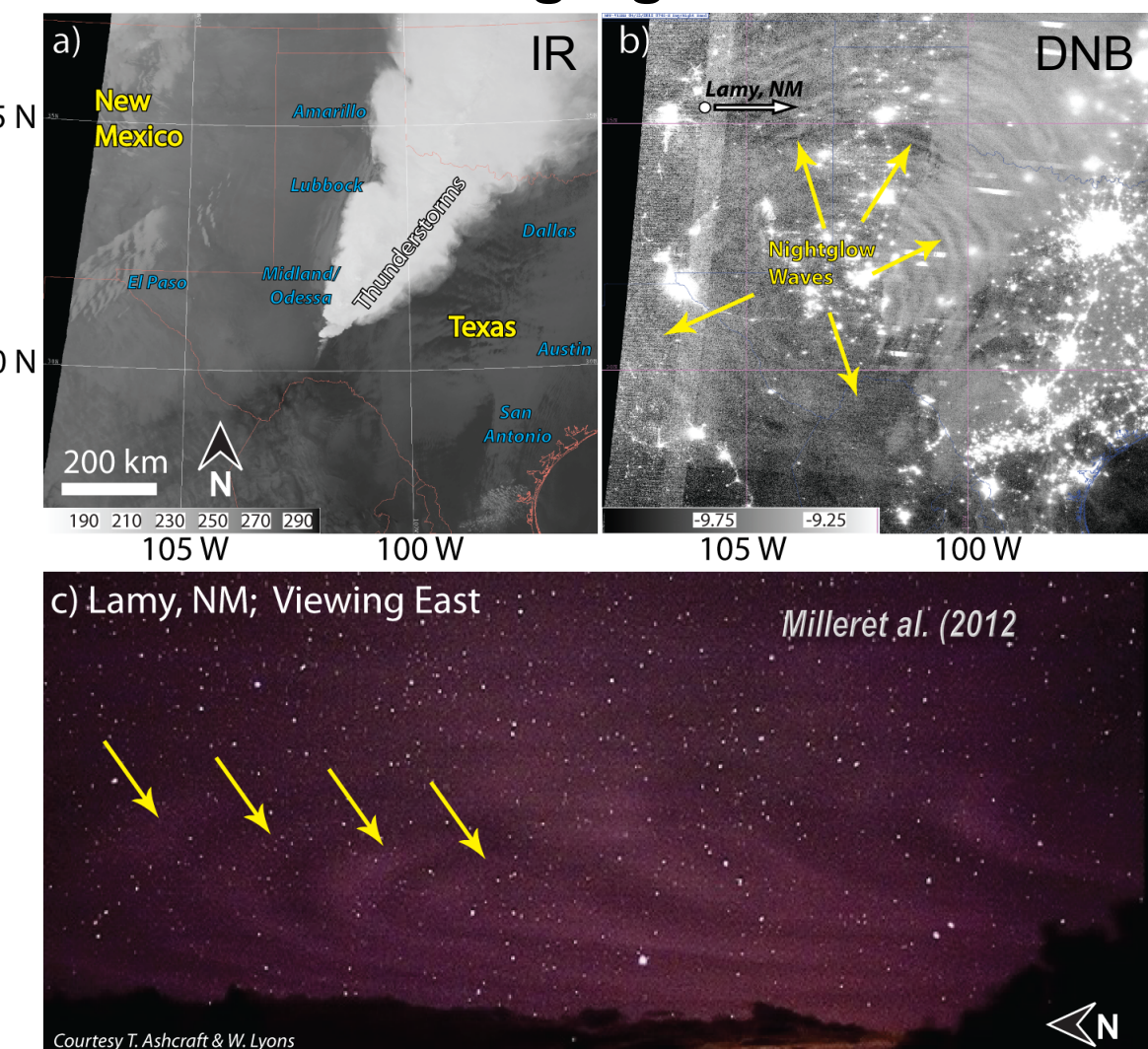
Nightglow

DNB sensitivity and response enables detection of nightglow, including gravity wave perturbations.

Lightning Flashes

The DNB scans 16 lines at a time, such that lightning flashes appear as ~12 km segments near storm tops.

Ship Lights
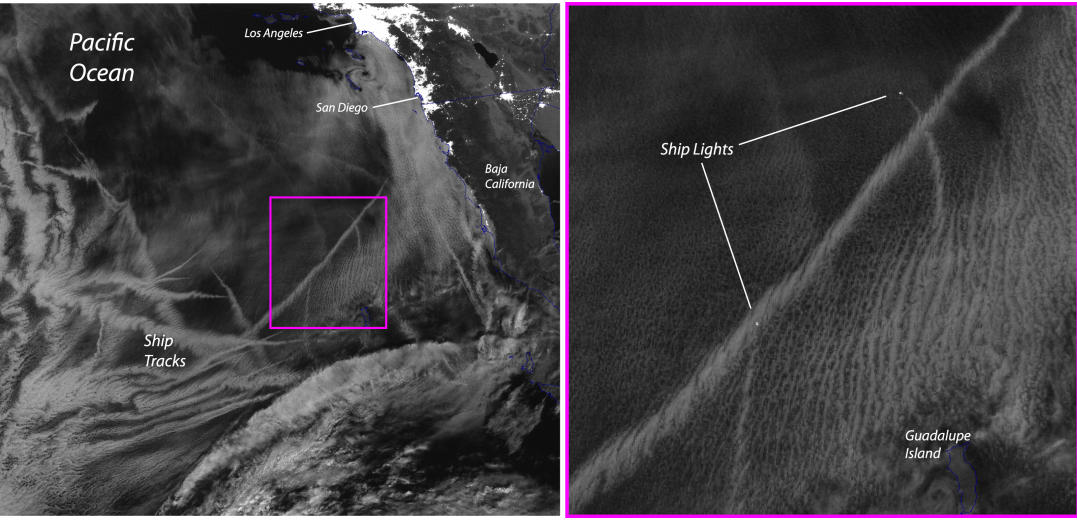
Lights emitted by commercial and fishing vessels are readily detectable as point sources of light.

Gas Flares

Similar to ship lights, natural gas flares appear as point sources. The Bakken shale formation in North Dakota indicates heavy mining activities in the area.

Aurora

Aurora borealis and australis (e.g above) are readily detectable by the DNB during both moon and moon-free conditions (Seaman et al., 2015).

Power Outages

Departures from 'stable light' backgrounds show coastal destruction in the wake of Hurricane Sandy.

Volcanic Magma

Departures from 'stable light' distributions show coastal destruction in the wake of Hurricane Sandy.

Search and Rescue

Air Algérie Flight 5017 crashed in bad weather, claiming 116 lives. S-NPP flew over within minutes of the crash, pinpointing a site whose location was initially unclear.
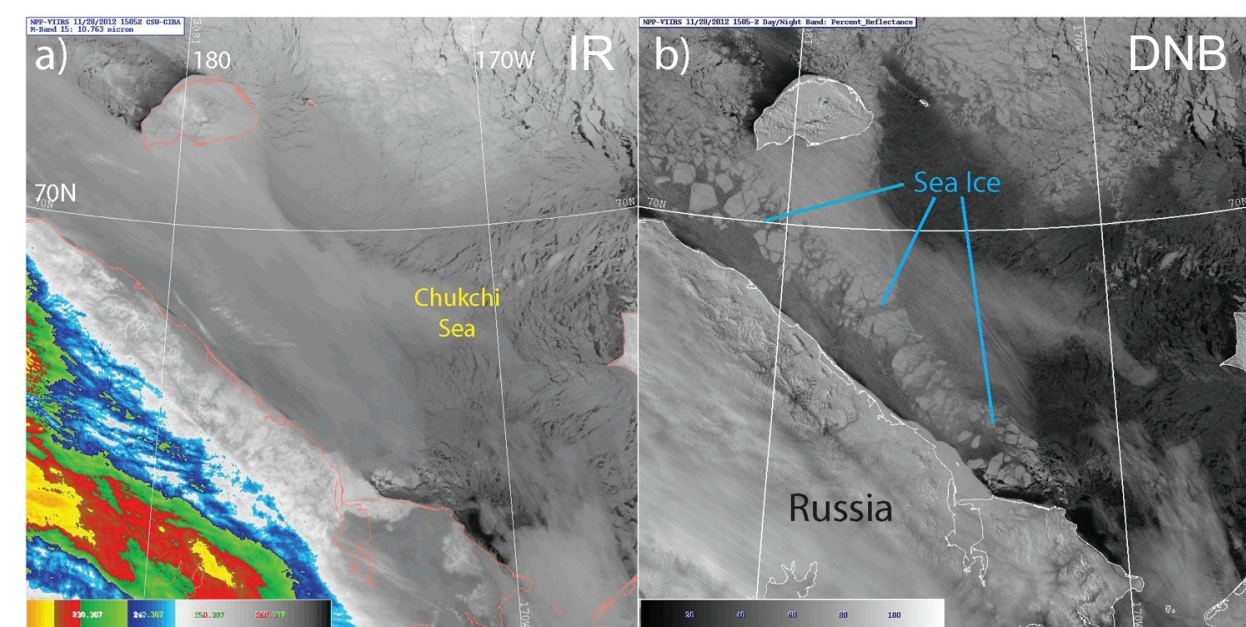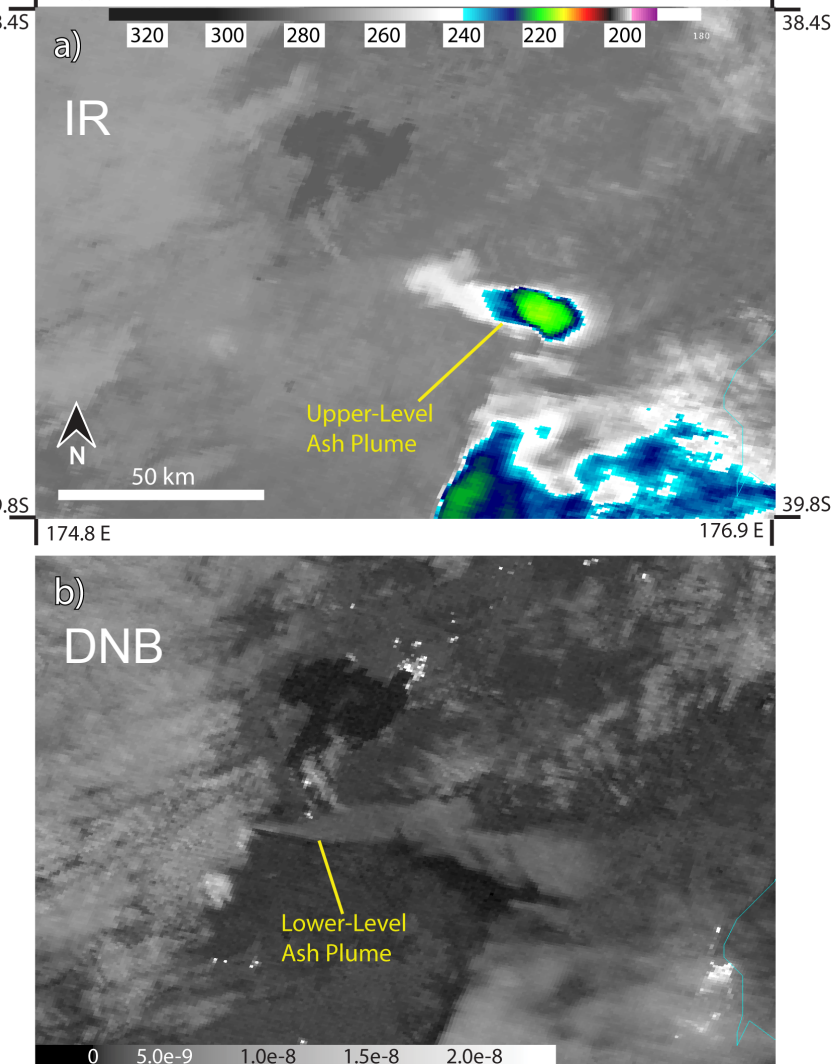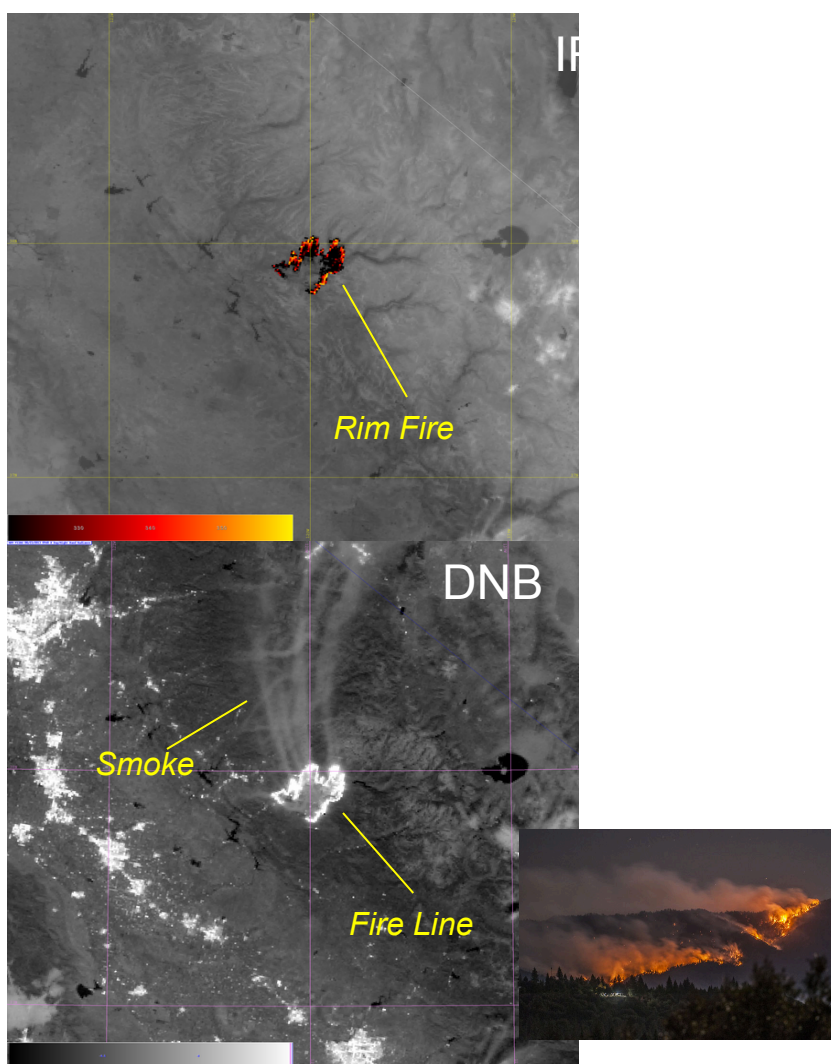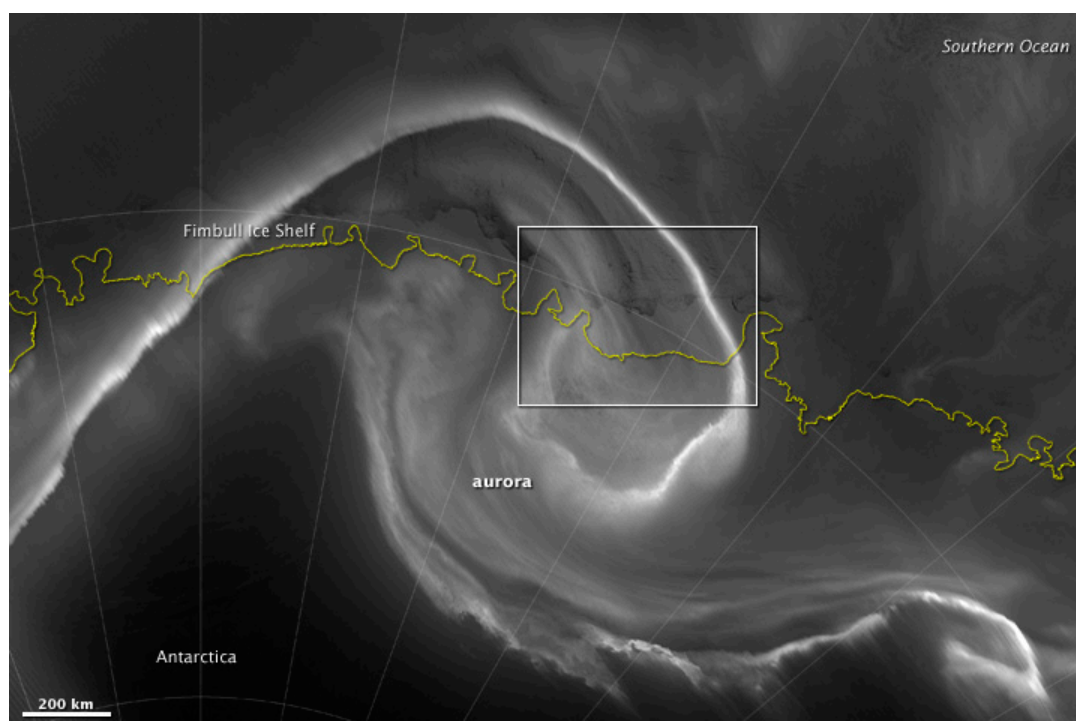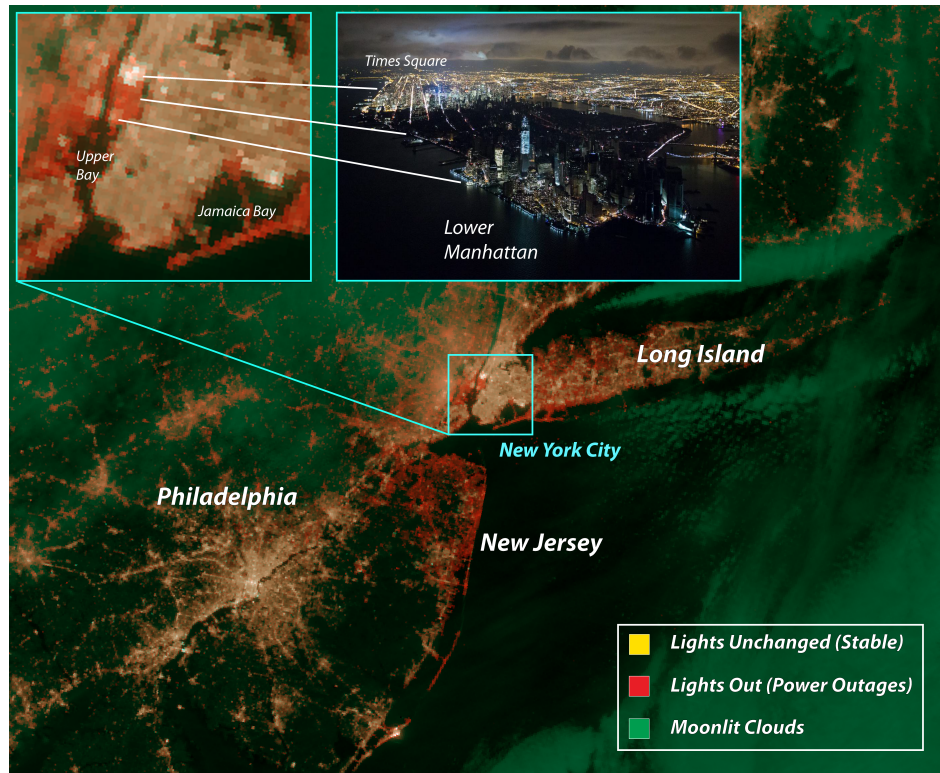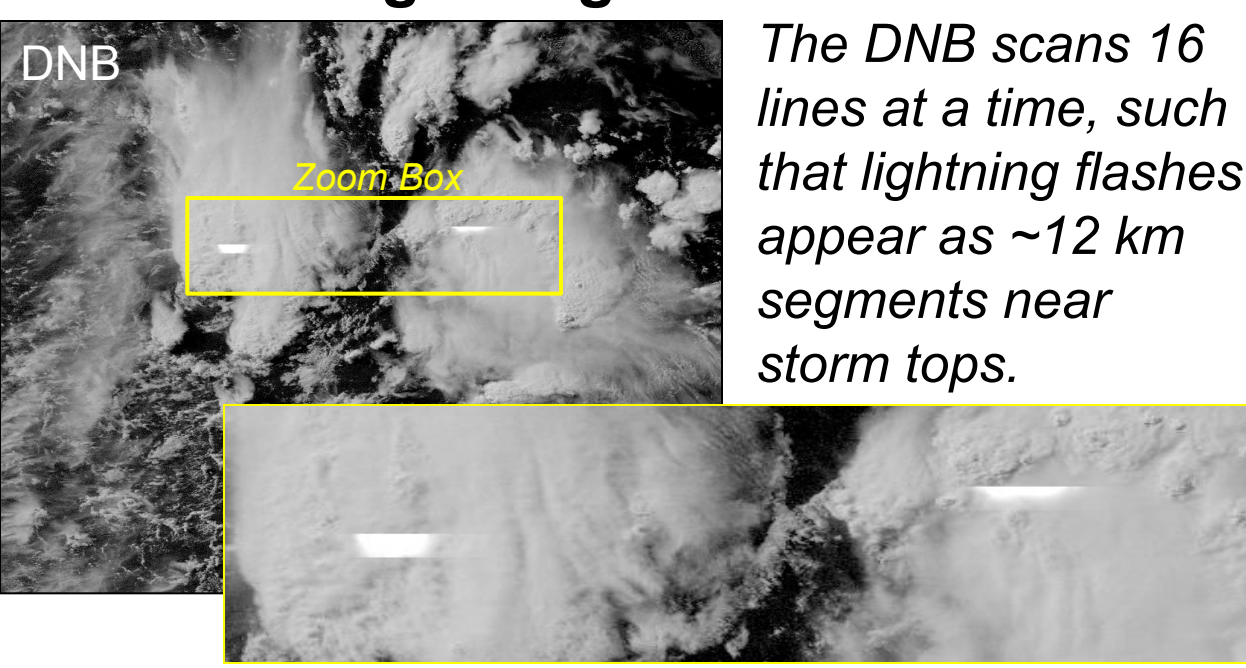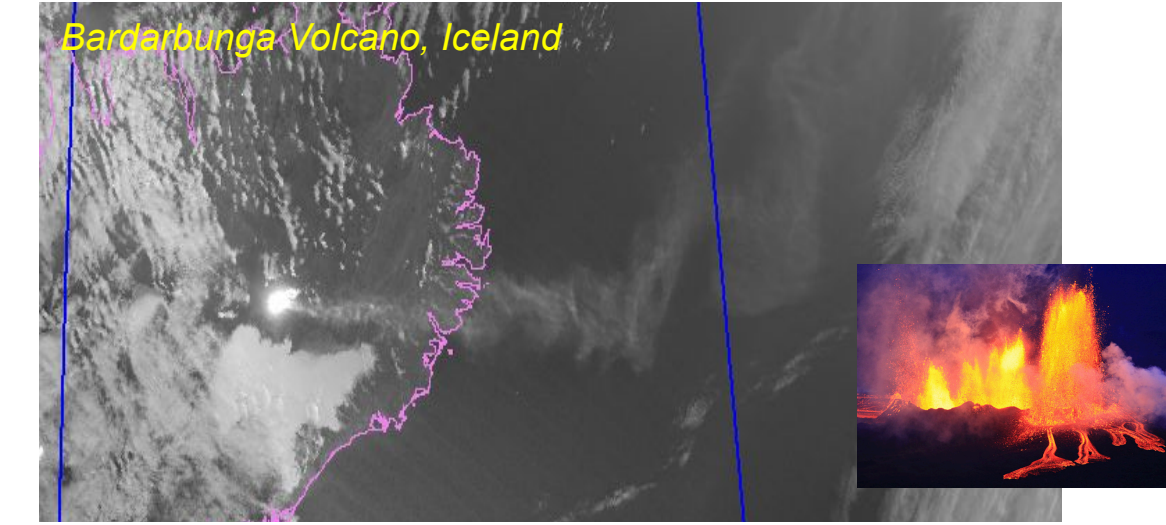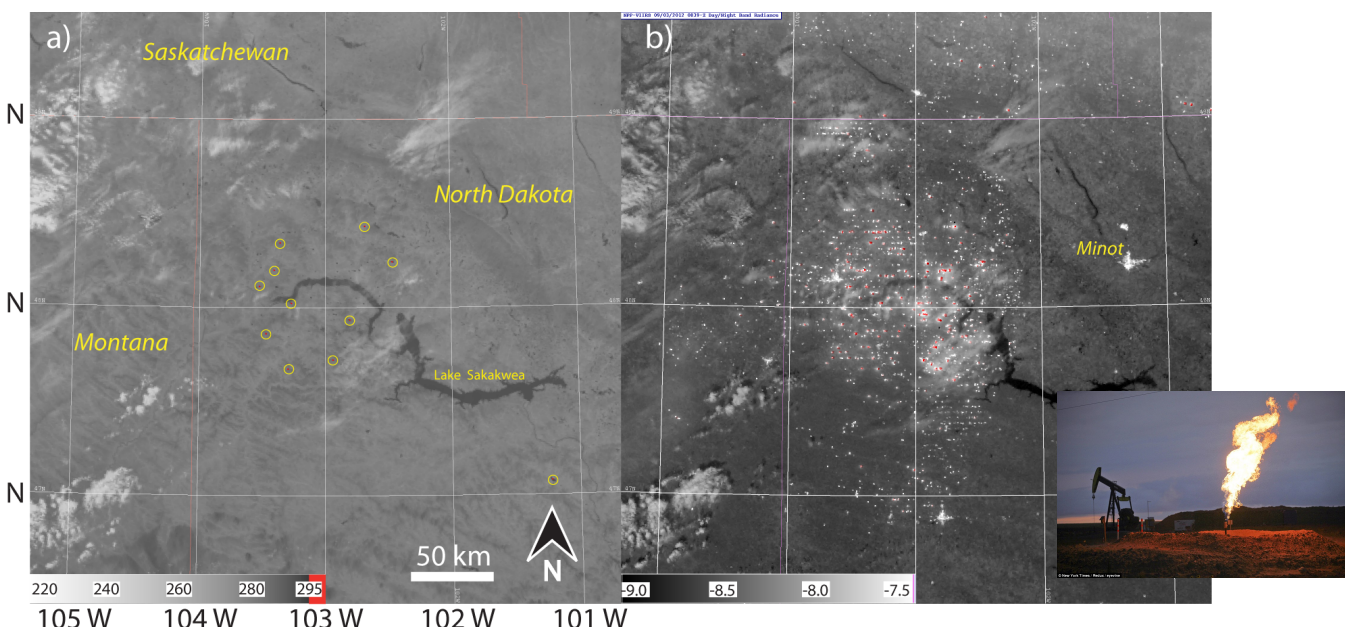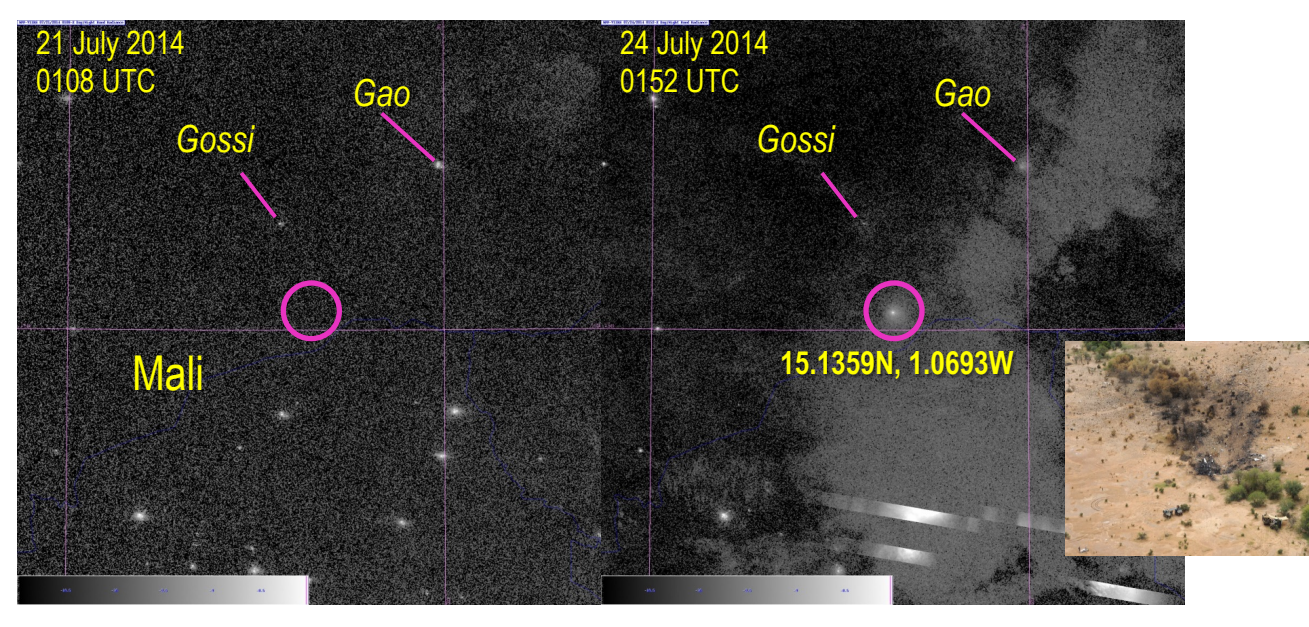
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